

CLAIMS

What is claimed is:

- 1 1. A beam steering module comprising:
 2 one or more beam steering elements, wherein the one or
 3 more beam steering elements deflect one or more optical
 4 signals in two dimensions, wherein the module can co-
 5 operate interchangeably with one or more optical
 6 components in an optical beam steering device.
- 1 2. The module of claim 1 wherein the optical component
 2 includes a reflector.
- 1 3. The module of claim 1 further comprising a
 2 collimator array mechanically coupled to module and
 3 optically coupled to beam steering elements.
- 1 4. The module of claim 3, wherein the collimator
 2 array is removably attached to the module.
- 1 5. The module of claim 1 wherein the optical component
 2 includes one or more other beam steering modules.
- 1 6. The module of claim 5, wherein the beam
 2 steering modules are part of an optical switch.
- 1 7. The module of claim 1 wherein the optical signals
 2 enter and leave the module along substantially
 3 parallel paths.
- 1 8. The module of claim 1, further comprising one or
 2 more collimators optically coupled to the one or
 3 more beam steering elements.

1 9. The module of claim 8, further comprising an
2 array of photodetectors clustered around one or
3 more of said one or more collimators.

1 10. The module of claim 1, further comprising at least
2 one fiber coupler having a hole coupled to the
3 module.

1 11. the module of claim 10 further comprising a
2 collimator disposed in the hole.

1 12. The module of claim 1, wherein the one or more beam
2 steering elements include a first deflector array
3 optically coupled to a second deflector array,
4 wherein the first and second deflector arrays co-
5 operate to steer an optical signal in two
6 dimensions.

1 13. The module of claim 12, wherein one or more of
2 the first and second deflector arrays includes
3 an LxM array of deflectors, where L and M are
4 integers greater than or equal to one.

1 14. The module of claim 13, wherein N first
2 and second deflector arrays are stacked to
3 form an NxLxM beam steering module, where
4 N is an integer greater than or equal to
5 1.

1 15. The module of claim 12, wherein one or more of
2 the beam steering elements includes a frame,
3 wherein the first and second arrays are coupled
4 to opposite sides of the frame in a staggered
5 configuration.

- 1 16. The module of claim 15 wherein the frame
2 includes one or more holes between the two
3 or more arrays one at least one side of
4 the frame.
- 1 17. The module of claim 12, wherein at least one of
2 the first and second arrays is a double-sided
3 array.
- 1 18. The module of claim 17, wherein the double
2 sided array includes two substrates back-
3 to-back, wherein each substrate has one or
4 more deflectors on one side.
- 1 19. The module of claim 18 wherein the
2 back-to-back substrates are separated
3 by an air gap.
- 1 20. The module of claim 17, wherein the double
2 sided array includes a single substrate
3 having one or more deflectors on each side
4 thereof.
- 1 21 The module of claim 12, wherein the first array
2 includes one or more deflectors configured to
3 rotate about a single first axis.
- 1 22 The module of claim 21 further comprising
2 relay optics optically coupled to one or
3 more of the first and second deflector
4 arrays.
- 1 23 The module of claim 21 wherein the second
2 array includes one or more deflectors

3 configured to rotate about a single second
4 axis.

1 24. The module of claim 23 wherein the
2 first axis is substantially
3 perpendicular to the second axis.

1 25. The module of claim 23 wherein the
2 deflectors in the first and second
3 arrays are optically coupled in a
4 one-to-one correspondence.

1 26. The module of claim 23, wherein at
2 least one of the first and second
3 deflector arrays is a double-sided
4 array.

1 27. The module of claim 23 wherein N
2 first and second deflector arrays are
3 stacked.

1 28. The module of claim 23 further
2 comprising relay optics optically
3 coupled to one or more of the first
4 and second deflector arrays.

1 29. The module of claim 21, wherein at least one of
2 the first and second arrays is double-sided
3 array.

1 30. The module of claim 29 wherein the double-
2 sided array includes one or more
3 deflectors on one side configured to
4 rotate about a first axis and one or more

5 deflectors on another side configured to
6 rotate about a second axis.

1 31. The module of claim 29, wherein N of said
2 double-sided arrays are stacked, wherein N
3 is an integer greater than 1.

1 32. The module of claim 12, wherein the first
2 deflector array includes one or more dual-axis
3 deflectors configured to rotate about a first
4 axis and a second axis.

1 33. The module of claim 32 wherein the second
2 array includes one or more fixed
3 deflectors.

1 34. The module of claim 32, wherein the one or
2 more dual-axis deflectors includes one or
3 more double-sided dual axis deflectors.

1 35. The module of claim 34, wherein the
2 one or more double-sided dual axis
3 deflectors includes two substrates
4 back-to-back, wherein each substrate
5 has one or more deflectors on one
6 side.

1 36. The module of claim 35 wherein
2 the back-to-back substrates are
3 separated by an air gap.

1 37. The module of claim 34, wherein the
2 one or more double-sided dual-axis
3 deflectors includes a single

4 substrate having one or more
5 deflectors on each side thereof.

1 38. The module of claim 32 wherein the second
2 deflector array includes one or more
3 double-sided fixed deflectors.

1 39. The module of claim 38, wherein the
2 one or more double-sided fixed
3 deflectors includes two substrates
4 back-to-back, wherein each substrate
5 has one or more deflectors on one
6 side.

1 40. The module of claim 39 wherein
2 the back-to-back substrates are
3 separated by an air gap.

1 41. The module of claim 38, wherein the
2 one or more double-sided fixed
3 deflectors includes a single
4 substrate having one or more
5 deflectors on each side thereof.

1

1 42. An optical switch, comprising:
2 a) a first beam steering module;
3 b) a second beam steering module optically coupled to
4 the first beam steering module;
5 wherein at least one of the first and second beam
6 steering modules includes at least one beam steering
7 element, wherein the at least one beam steering element
8 deflects an optical signal in two dimensions, wherein at

9 least one of the first and second modules can co-operate
10 interchangeably with one or more optical components in
11 the optical switch.

1 43. The switch of claim 42 wherein the optical signals
2 enter and leave the module along substantially
3 parallel paths.

1 44. The switch of claim 42, further comprising one or
2 more collimators coupled to the at least one beam
3 steering element.

1 45. The switch of claim 42, further comprising a fiber
2 coupler connected to one or more of the first and
3 second beam steering modules, the fiber coupler
4 having hole.

1 46. The switch of claim 45, further comprising a
2 collimator disposed in hole.

1 47. The switch of claim 42, further comprising a
2 collimator array mechanically coupled to one or more
3 of the first and second beam steering modules,
4 wherein the collimator array is optically coupled to
5 the at least one beam steering element.

1 48. The switch of claim 42, wherein the at least one
2 beam steering element includes a stack containing
3 one or more first deflector arrays optically coupled
4 to one or more second deflector arrays wherein one
5 or more of the first and second deflector arrays
6 includes a double sided array having on one side one
7 or more deflectors configured to rotate about a
8 single first axis, the double sided array having on

9 another side one more deflectors configured to
10 rotate about a single second axis.

1 49. The switch of claim 48 further comprising relay
2 optics optically coupled to one or more of the
3 first and second beam steering elements.

1 50. The switch of claim 49, further comprising
2 relay optics coupled to one or more of the
3 first and second modules.

1 51. The switch of claim 49 wherein the first
2 and second beam steering modules are part
3 of a plurality of first and second beam
4 steering modules disposed along a curved
5 surface.

6 52. The switch of claim 51 further
7 comprising a fold deflector optically
8 coupled between the first and second
9 beam steering modules.

1 53. The switch of claim 52 wherein
2 the fold deflector is partially
3 transparent.

1 54. The fold deflector of claim 53,
2 further comprising a
3 photodetector array optically
4 coupled to the partially
5 transparent fold deflector.

1 55. The switch of claim 42, wherein the at least one
2 beam steering element includes a stack containing
3 one or more first deflector arrays optically coupled

4 to one or more second deflector arrays wherein one
5 or more of the first and second deflector arrays
6 includes a double sided array having on one side one
7 or more deflectors configured to rotate about a
8 first axis and a second axis, the double sided array
9 having on another side one more fixed deflectors.

1 56. The switch of claim 55 wherein the first and
2 second beam steering modules are part of a
3 plurality of first and second beam steering
4 modules disposed along a curved surface.

1 57. The switch of claim 56 further comprising
2 a fold deflector optically coupled between
3 the first and second beam steering
4 modules.

1 58. The switch of claim 42, wherein the one or more beam
2 steering elements includes a stack containing one or
3 more first deflector arrays optically coupled to one
4 or more second deflector arrays wherein one or more
5 of the first and second deflector arrays includes a
6 double sided array having on one side one or more
7 fixed deflectors, the double sided array having on
8 another side one more deflectors configured to
9 rotate about a first axis and a second axis.

1 59. The switch of claim 58 wherein the first and
2 second beam steering modules are part of a
3 plurality of first and second beam steering
4 modules disposed along a curved surface.

1 60. The switch of claim 59 further comprising
2 a fold deflector optically coupled between

3 the first and second beam steering
4 modules.

1 61. The switch of claim 42, further comprising a fold
2 deflector optically coupled between the first and
3 second.

1 62. The switch of claim 61, wherein the fold
2 deflector is a curved fold mirror.

1 63. The switch of claim 62, wherein the first
2 and second modules are arranged in a
3 substantially planar configuration.

1 64. The switch of claim 62, wherein the first
2 and second modules are arranged in a
3 substantially curved configuration.

1 65. The switch of claim 42, wherein the first and second
2 modules are arranged in a substantially planar
3 configuration.

1 66. The switch of claim 42, wherein the first and second
2 modules are arranged in a substantially curved
3 configuration.

1 67. An optical switch comprising at least one beam steering
2 module having at least one beam steering element, wherein
3 the at least one beam steering element deflects an
4 optical signal in two dimensions, wherein the module can
5 co-operate interchangeably with one or more optical
6 components in the optical switch.

1 68. The optical switch of claim 67 further comprising a
2 fold deflector coupled to the at least one beam
3 steering module.

1 69. The optical switch of claim 67, wherein the optical
2 components include one or more other beam steering
3 modules.

1 70. The optical switch of claim 71 wherein the at least
2 one beam steering module is removable from the
3 switch.

1 71. The optical switch of claim 71 further comprising a
2 power tap optically coupled to the beam steering
3 element, the switch further comprising a controller
4 coupled to beam steering element and the power tap
5 in a feedback loop.

6 72. The switch of claim 71 further comprising a
7 calibration light source coupled to the beam
8 steering element and power tap.

9 73. fixed frequency light that doesn't
10 conflict with signal frequency,

1 74. The switch of claim 67, wherein the optical signals
2 enter and leave the switch along substantially
3 parallel paths.

1 75. The switch of claim 67, further comprising one or
2 more collimators optically coupled to the beam
3 steering element.

1 76. The switch of claim 67 further comprising a fiber
2 coupler connected to one or more of the first and

3 second beam steering modules, the fiber coupler
4 having hole.

1 77. The switch of claim 77, further comprising a
2 collimator disposed in hole.

1 78. The switch of claim 67, wherein the at least one
2 beam steering element includes a first deflector
3 array optically coupled to a second deflector array.

1 79. The switch of claim 78, wherein one or more of
2 the first and second deflector arrays includes
3 an $L \times M$ array of deflectors, where L and M are
4 integers greater than or equal to one.

1 80. The switch of claim 79, wherein N of said
2 $L \times M$ arrays are stacked to form an $N \times L \times M$
3 beam steering element.

1 81. The switch of claim 78, wherein the at least
2 one beam steering element includes a frame
3 wherein the first and second arrays are coupled
4 to opposite sides of the frame in a staggered
5 configuration the frame w/holes to let beams
6 pass.

1 82. The switch of claim 78, wherein at least one of
2 the first and second deflector arrays includes
3 one or more double-sided arrays of deflectors.

1 83. The switch of claim 78, wherein the first array
2 includes one or more deflectors configured to
3 rotate about a single first axis.

1

84. The switch of claim 83, wherein the second array includes one or more deflectors configured to rotate about a single second axis.

2

3

4

1

85. The switch of claim 84 wherein the first and second arrays include one or more stacked double-sided arrays.

2

3

1

86. The switch of claim 84 wherein the deflectors in the first array are optically coupled to the deflectors in the second array in a one-to-one correspondence.

2

3

4

5

1

87. The switch of claim 84, further comprising relay optics optically coupled to one or more of the first and second arrays.

2

3

4

1

88. The switch of claim 84 wherein the first axis is substantially perpendicular to the second axis.

2

3

1

89. The switch of claim 83, wherein the first and second arrays include one or more double-sided arrays.

2

3

1

90. The switch of claim 83, wherein the first and second arrays include one or more stacked double-sided arrays.

2

3

- 1 91. The switch of claim 83, further comprising
2 relay optics optically coupled to one or
3 more of the first and second arrays.
- 1 92. The switch of claim 78, wherein the first array
2 includes one or more dual-axis deflectors
3 configured to rotate about a first axis and a
4 second axis.
- 1 93. The switch of claim 92, wherein the second
2 array includes one or more fixed
3 deflectors.
- 4 94. The switch of claim 93 wherein the
5 one or more fixed deflectors is a
6 single continuous fixed deflector.
- 1 95. The switch of claim 92, wherein the one or
2 more dual-axis deflectors includes one or
3 more double-sided dual axis deflectors
- 4 96. The switch of claim 95, wherein the
5 second array includes a single
6 continuous fixed deflector.
- 7 97. The switch of claim 95 wherein the
8 one or more dual-axis deflectors
9 includes a double-sided dual-axis
10 deflector optically coupled to a double-
11 sided fixed deflector in a sandwich.
- 12 98. The switch of claim 97 wherein a
13 plurality of said sandwiches are
14 stacked.

1 99. The switch of claim 92, wherein one or
2 more of the first and second arrays
3 includes a double-sided array having one
4 or more dual-axis deflectors on one side
5 and one or more fixed deflectors on the
6 other side.

1 100. The switch of claim. 99, wherein a
2 plurality of said double-sided arrays
3 are stacked.

1 101. An optical switch, comprising:

- 2 a) a first set of optical I/O ports distributed across
3 a first curved surface;
4 b) a second set of optical I/O ports distributed across
5 a second curved surface; and
6 c) a set of beam steering elements optically coupled
7 between the set of inputs and the set of outputs.

1 102. The switch of claim 101, further comprising a fold
2 deflector optically coupled between the first and
3 second sets of I/O ports.

1 103. The switch of claim 102, wherein the fold deflector is
2 a curved fold mirror.

1 104. The switch of claim 101, wherein the first and
2 second surfaces are in a substantially offset
3 alignment with respect to one another and said beam
4 steering elements include one-way scanning
5 deflectors.

1 105. The switch of claim 101, wherein the first and
2 second surfaces are in a substantially opposed

3 alignment with respect to one another and said beam
4 steering elements include two-way scanning
5 deflectors.

1 106. The switch of claim 101, wherein the beam steering
2 elements are arranged in one or more modules.

1 107. The switch of claim 106, wherein the one or more
2 modules includes one or more I/O ports.

1 108. The switch of claim 107, wherein the one or
2 more modules are distributed across one or
3 more of the first and second curved
4 surfaces.

1 109. The optical switch of claim 106, wherein the one or
2 more modules include:

3 i) a first array of one or more deflector
4 elements, and

5 ii) a second array of one or more deflector
6 elements disposed proximate the first
7 linear array, wherein the first and second
8 linear arrays are substantially parallel
9 to one another,

10 wherein each deflector element in the
11 first array is optically coupled to a
12 corresponding deflector element in the
13 second array in a one to one
14 correspondence, wherein at least one of
15 the first and second linear arrays
16 includes one or more steerable deflectors,
17 whereby the beam steering module may steer
18 one or more optical signals in two
19 dimensions.

1 110. The switch of claim 109, wherein at least one
2 of the first and second arrays is a linear
3 array.

4 111. The switch of claim 106, wherein at least
5 one of the arrays includes deflectors on
6 two sides of the array.

1 112. The switch of claim 106, wherein the first
2 array includes one or more deflectors
3 configured to rotate about a first single
4 axis.

1 113. The switch of claim 112, wherein the
2 second array includes one or more
3 deflectors configured to rotate about
4 a second single axis.

1 114. The switch of claim 113 further
2 comprising relay optics
3 optically coupled to one or more
4 of the first and second arrays.

1 115. The switch of claim 113, wherein
2 the first axis is substantially
3 perpendicular to the second
4 axis.

1 116. The switch of claim 109 wherein the first array
2 includes one or more dual-axis deflectors
3 configured to rotate about a first axis and a
4 second axis.

- 1 117. The switch of claim 116, wherein the
- 2 second array includes one or more fixed
- 3 deflectors.

1

117. The switch of claim 116, wherein the second array includes one or more fixed deflectors.